

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 155.

B. T. GALLOWAY, *Chief of Bureau.*

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# THE CONTROL OF BLACK-ROT OF THE GRAPE.

BY

C. L. SHEAR, PATHOLOGIST,

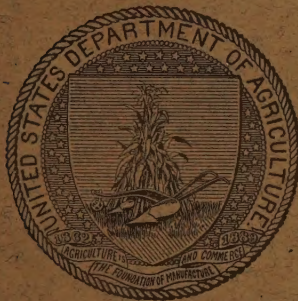
AND

GEORGE F. MILES AND LON A. HAWKINS,

SCIENTIFIC ASSISTANTS, FRUIT DISEASE INVESTIGATIONS.

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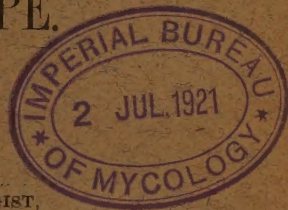
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[Continued on page 3 of cover.]







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## BUREAU OF PLANT INDUSTRY.

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*Chief of Bureau,* BEVERLY T. GALLOWAY.  
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### FRUIT DISEASE INVESTIGATIONS.

#### SCIENTIFIC STAFF.

M. B. Waite, *Pathologist in Charge.*

C. L. Shear, *Pathologist in Charge of Small Fruit Disease Investigations.*

W. M. Scott, *Pathologist in Charge of Orchard Spraying Experiments and Demonstrations.*

P. J. O'Gara, G. F. Miles, W. A. Ballard, Lon A. Hawkins, Mrs. Anna K. Wood, T. W. Ayres, Clara H. Hasse, and F. V. Rand, *Scientific Assistants.*

F. W. Faurot, *Agent and Expert.*

## LETTER OF TRANSMITTAL

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U. S. DEPARTMENT OF AGRICULTURE,  
BUREAU OF PLANT INDUSTRY,  
OFFICE OF THE CHIEF,  
*Washington, D. C., May 10, 1909.*

SIR: I have the honor to transmit herewith a paper entitled "The Control of Black-Rot of the Grape," a report of three seasons' spraying experiments by Dr. C. L. Shear, Pathologist, and Messrs. George F. Miles and Lon A. Hawkins, Scientific Assistants, of this Bureau, and recommend its publication as Bulletin No. 155 of the series of the Bureau of Plant Industry.

The paper contains the results of grape spraying experiments conducted in New York, New Jersey, Pennsylvania, and Michigan. The work shows conclusively that the most serious epidemics of black-rot, such as prevailed in Michigan, can be satisfactorily controlled by thorough and proper methods of spraying. It also indicates that smaller quantities of copper sulphate and lime than have heretofore been thought necessary in the preparation of Bordeaux mixture will give just as satisfactory results as the stronger mixtures.

Respectfully,

B. T. GALLOWAY,  
*Chief of Bureau.*

HON. JAMES WILSON,  
*Secretary of Agriculture.*







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# THE CONTROL OF BLACK-ROT OF THE GRAPE.

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## INTRODUCTION.

Ever since the beginning of commercial grape growing in the eastern United States, black-rot has been one of the most serious enemies with which vineyardists have had to contend. It is now more than twenty years since the introduction of spraying for grape diseases in this country. During this period much work upon this subject has been done by the Department of Agriculture and the State agricultural experiment stations, and as a result many improvements have been made in the formulas and the preparation of fungicides, and in the methods of applying them. These have resulted in much more efficient work and also in a reduction of the cost of the operations.

The continued success of commercial grape growing in any of the humid portions of this country has heretofore largely depended upon the successful control of the fungous diseases. Virginia, North Carolina, Florida, southern Ohio, Missouri, and New Jersey have each during the last seventy-five years been important grape-growing centers. Grape growing has arisen and flourished in various parts of the eastern United States only to decline and be largely abandoned after having passed through a severe epidemic or series of epidemics of black-rot. Notwithstanding the success which has been attained in recent years by the Department of Agriculture and the agricultural experiment stations, these outbreaks are not usually satisfactorily controlled by the growers. Black-rot still causes heavy losses and continues to threaten the industry in various localities.

Unsatisfactory results from spraying are according to our observations most generally due to lack of thoroughness in the application of the fungicide. In many cases improperly prepared mixtures and poor apparatus are also important causes of failure. Without an opportunity to observe in actual operation the various processes connected with the proper preparation and application of fungicides, it seems to be difficult for many persons to carry out satisfactorily the most successful methods of spraying. One who undertakes spraying for the first time and does the work, as he thinks, in accordance with the best method and yet only meets with indifferent success or failure is quite likely to lose confidence in the treatment or to condemn it entirely. It is therefore very important that the subject

should be thoroughly understood and the work properly carried out from the beginning.

Owing to the failure of many vineyardists in their efforts to prevent black-rot, a series of investigations was undertaken to demonstrate the efficiency of the best methods at present practiced and at the same time to improve, if possible, both methods and mixtures and also to secure more accurate knowledge of the life history and habits of the black-rot fungus and of the other parasitic fungi which are more or less destructive to the grape. This work was commenced in the spring of 1906 at North East, Pa. In 1907 it was extended to central New York and Michigan, and the past season, 1908, it has been carried on in Pennsylvania, New York, Michigan, and New Jersey. In order to determine the various factors influencing the black-rot fungus and its successful control, as well as the relative importance and relation of these factors, it seemed necessary to carry on the work at different points which should represent different soils and climatic conditions as well as with different varieties of grapes and methods of training and cultivation.

#### THE CAUSE OF BLACK-ROT.

Black-rot is caused by a parasitic fungus known botanically as *Guignardia bidwellii*. It is a vegetable organism which reproduces and spreads by means of minute microscopic bodies called spores. These are borne in small black globose bodies which may be seen covering the surface of mummied grapes which have been destroyed by rot. This parasite produces two well-known spore forms, as shown in figure 1. These are somewhat similar in appearance and differ chiefly in the way in which they are produced. The so-called summer spores are borne on the ends of small, slender threads, and when mature are set free and escape in white tendril-like masses through an opening at the apex of the minute spore case. This form usually occurs first upon the grape leaves in the shape of small black pustules scattered over a reddish or whitish more or less circular dead spot. If a little later the weather conditions are favorable the fungus may be found attacking the flower buds or very young fruit, which may be destroyed at any time from the setting of the fruit to near the maturity of the berries. Fruit which is attacked when very young turns black and soon drops off, and this stage of the disease is frequently called blight or blast. Later, when the berries are one-third grown or larger, the disease usually starts in the form of a sordid white spot, which increases more or less rapidly in size until the whole berry is affected and begins to shrivel, and sooner or later becomes covered with the minute black pustules of the black-rot fungus. What is frequently called "bird's-eye," or anthracnose, by growers in New York and Pennsylvania is a condition of development due to



the black-rot fungus and is not the true anthracnose. A form of the disease in which the berries rot rapidly and become soft is sometimes called soft-rot. Besides the leaves and fruit the fungus also attacks the young shoots, producing numerous small, reddish brown spots.

During the autumn and winter the fungus continues to grow when conditions are favorable, and the second spore form is produced. These spores, sometimes called winter spores, grow inside of a minute sac and are usually eight in number, as shown in figure 1, *c*. These sacs with their spores are produced inside of small black pustules very closely resembling those which contain the free summer spores. There are several points in regard to the life history of this fungus and the various means by which infection is accomplished which are not yet thoroughly understood, and much more work is needed to verify and extend our knowledge of these matters.



FIG. 1.—The black-rot fungus (*Guignardia bidwellii*): *a*, A portion of an affected grape, showing the pustules in which the spores are produced (slightly magnified); *b*, a section of one of these pustules very highly magnified, showing the manner in which the summer spores are produced and discharged; *c*, a sac containing winter spores; *d*, single winter spores very highly magnified.

The first infection of the young foliage and buds in the spring is believed to come from the winter spores which are expelled from the mature fruiting pustules of the fungus and are driven by the wind and rain to the young growing parts of the vine. These spores are usually produced upon the old black-rot mummies from spring until late summer whenever sufficient moisture in the form of rain, fog, or dew is present, and they are regarded as a source of infection during that period. The fungus having gained entrance to the leaves, shoots, or young fruit may immediately begin to produce the summer spores which, when discharged and distributed to the fruit and other

parts of the plant, may produce further infection and disease. So far as known at present, after the fungus has gained entrance to the tissue of the leaf or has gotten beneath the skin of the berry its further development under favorable climatic conditions can not be prevented by any practical means; hence, all measures to be undertaken against the disease must be directed toward preventing the fungus from gaining entrance to the plant and reproducing itself. The winter spores borne upon the old mummied grapes are regarded as one of the chief sources of early infection, and any practical means of destroying or preventing the distribution of these spores should tend to restrict the spread of the disease. That this is a matter of great importance has been shown by observations made during the course of this work. Vines located near unsprayed plants in an adjoining vineyard which had an abundance of black-rot mummies were much more seriously affected by the rot than those which were farther removed from this source of infection. Where black-rot is serious it will be found profitable, in the opinion of the writers, to destroy or bury all the old mummied grapes in the vineyard. At the time of pruning, all diseased grapes which are still hanging on the vines should be picked and burned or buried deeply and all the mummies on the ground should be either raked up and burned or else buried deeply by plowing. All the prunings from the vineyard should also be destroyed by burning, as the diseased shoots may produce spores of the black-rot fungus.

Having destroyed or removed as far as practicable the source of infection, the next step is to protect the entire plant as nearly as possible from any spores which may reach it, and this is accomplished in practice by spraying with fungicides. These are composed of chemicals which prevent the germination of the fungous spores with which they come in contact. If, therefore, every portion of a grape plant which may form a point of entrance for the fungus is covered with a film of a fungicide like Bordeaux mixture, any spores which may be present at the time the fungicide is applied or any others which may fall upon the plant before the fungicide has been washed off or removed in any way will be destroyed; hence, what is desired in spraying is to cover the plant as nearly as possible with a very thin film of the fungicide and to keep the plant covered during the portion of the season when infection is likely to occur. In order to accomplish this, the very best nozzles and spraying machines must be used and handled by persons who are very careful and thorough in their work. The fungicides used must be carefully prepared according to the best methods and formulas.

The technical investigations of the various problems have not yet been completed; therefore, only the results of immediate practical importance are reported at this time.

## THE FUNGICIDES USED.

In the trial of various fungicides several purposes were kept in view: First, the efficiency of the fungicide; second, its economy as determined by the cost of material and its preparation and application; and, third, in the case of nonstaining applications, efficiency as compared with cost and injury to the fruit by staining. Following are the formulas of the different preparations used:

*Bordeaux mixture*.—Commercial copper sulphate, fresh stone lime, and water, in the order given, were prepared according to the following formulas:<sup>a</sup>

6-3-50 (For first application only, before buds burst.)  
 5-5-50  
 5-4-50  
 5-3-50  
 4-4-50  
 4-3-50  
 4-2-50  
 3-3-50  
 3-2-50  
 3-1-50 (For final application only.)

According to recent investigations of the chemistry of Bordeaux mixture made by Pickering,<sup>b</sup> the addition of a greater quantity of lime than is sufficient to neutralize the copper sulphate and render it slightly alkaline interferes with the efficiency of the mixture as a fungicide. He maintains that any excess of lime must first be oxidized and disappear before the copper can be acted upon and become effective; thus, any excess of lime tends to retard the fungicidal action of the mixture and should never be added except for the purpose of protecting foliage which would be injured by mixtures not containing an excess of lime. Experiments made by Kelhofer<sup>c</sup> to determine the difference in the adhesive qualities of mixtures made with different quantities of lime gave the best results when two parts by weight of copper sulphate were used with but one part of lime. Such a mixture would be represented by our 4-2-50 formula. To the weaker solutions of Bordeaux mixture resin-fishoil soap was added for one or more of the applications to improve their adhesive qualities.

*Burgundy mixture*.—Three formulas were used: (1) Composed of 1½ pounds of copper sulphate and 2 pounds of sodium carbonate to 50

<sup>a</sup> Whenever formulas for Bordeaux mixture are given in this paper the first number indicates the number of pounds of copper sulphate used; the second, the number of pounds of stone lime; and the last, the number of gallons of water.

<sup>b</sup> Pickering, Spencer. Interaction of Metallic Sulphates and Caustic Alkalis. Proc. Chem. Soc., vol. 23, p. 261. London, 1907.

<sup>c</sup> Kelhofer, W. Ueber einige Gesichtspunkt bei die Herstellung der Bordeauxbrühe. Inter. Phytopath. Dienst., vol. 1, p. 65. 1908.

gallons of water; (2) composed of 1 pound of copper sulphate and  $1\frac{1}{2}$  pounds of sodium carbonate to 50 gallons of water; (3) composed of  $1\frac{1}{4}$  pounds of copper sulphate and  $1\frac{1}{8}$  pounds of sodium carbonate to 50 gallons of water. The ingredients were dissolved separately and mixed in a dilute condition.

*Perdeux mixture.*—This is a preparation which was found in use in France and was very highly recommended. An analysis of a sample by the Bureau of Chemistry showed that it consisted of a mixture of pulverized copper sulphate and sodium carbonate, being essentially a form of Burgundy mixture. Preparing this in about the same proportions as indicated by the analysis, we have the following formula: 5 pounds of copper sulphate, 2 pounds of sodium carbonate, and 50 gallons of water. As might be expected from comparison with the formulas of the same constituents used in the Burgundy mixture, it was found impracticable to use this mixture on account of its severe injury to the foliage.

*Sodium benzoate Bordeaux mixtures.*—These mixtures were prepared as follows: (1) 2 pounds of copper sulphate, 1 pound of lime, and 1 pound of sodium benzoate to 50 gallons of water; (2) 1 pound of copper sulphate, 1 pound of lime, and one-half pound of sodium benzoate to 50 gallons of water. The ingredients were dissolved separately and mixed in a dilute condition.

*Copper borate mixture.*—Mixtures of this fungicide were prepared according to the following formulas: (1)  $1\frac{1}{2}$  pounds of copper sulphate, 2 pounds of borax, 50 gallons of water; (2)  $1\frac{1}{4}$  pounds of copper sulphate, 2 pounds of borax, 50 gallons of water; (3) 1 pound of copper sulphate, 2 pounds of borax, 50 gallons of water. Resin-fishoil soap was also added to most of these mixtures to improve their adhesive qualities and to determine the benefit to be derived from this source.

*Ammoniacal copper carbonate.*—This spray was prepared with 5 ounces of copper carbonate and 3 pints of ammonia to 50 gallons of water.

*Copper chlorid mixture.*—Prepared according to the following formula: 4 ounces of copper sulphate, 2 ounces of calcium chlorid, 50 gallons of water, with the addition of 1 pound of resin-fishoil soap.

*Normal copper acetate solution.*<sup>a</sup>—Prepared with one-half pound of normal copper acetate to 50 gallons of water.

*Neutral copper acetate solution.*<sup>b</sup>—Prepared by dissolving 1 pound of neutral copper acetate in 50 gallons of water.

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<sup>a</sup> The copper acetate used in some of the experiments was supplied under the name of normal copper acetate.

<sup>b</sup> In the work of 1908 all material used was purchased from the same source and labeled "neutral copper acetate." This form of copper acetate, the writers believe, is least apt to injure foliage and gives very good results as a fungicide.



*Basic copper acetate (verdigris solution).*—Prepared by dissolving 5 ounces of basic copper acetate in 50 gallons of water.

*Copper sulphate solution.*—Prepared with 3 pounds of copper sulphate to 50 gallons of water. Used as a dormant application only.

*Self-boiled lime-sulphur.*—(1) Prepared by mixing 8 pounds of flowers of sulphur with 15 pounds of stone lime, with the addition of hot water, diluting the whole to 50 gallons; also (2) 10 pounds of sulphur to 15 pounds of lime, with the same quantity of water.

*"A" brand concentrated lime-sulphur.<sup>a</sup>*—This mixture was used in two strengths: (1) 1 gallon of the concentrated preparation added to 50 gallons of water, and (2) 1 gallon added to 75 gallons of water.

*"B" brand concentrated lime-sulphur.<sup>a</sup>*—Prepared with 1 gallon of the concentrated solution added to 50 gallons of water.

#### METHOD OF MIXING.

The writers have practiced in all cases the method of preparing Bordeaux mixture which has heretofore been described in many of the publications of the Department of Agriculture and which is given in Farmers' Bulletin No. 284 in connection with the treatment of fungous diseases of the grape.

The copper sulphate and the lime are each diluted separately and thoroughly mixed together in a dilute form. Modifications of this method are said by some American and European pathologists to give equally good results, but the writers have not tested them as yet sufficiently to express an opinion.

### WORK IN PENNSYLVANIA.

#### EXPERIMENTS IN 1906.

For several years preceding 1906, the time this work was commenced, an epidemic of black-rot had prevailed in the grape belt in northwestern Pennsylvania, the center of which is North East. The work at this point was undertaken through an understanding with the Pennsylvania State College Agricultural Experiment Station and at the earnest solicitation of the grape growers.

The vineyard selected for the work consisted of 12 acres of Concord vines about 17 years old. The plots were 1.6 acres each and consisted of 10 rows, running east and west. There had been some loss from black-rot the preceding year, but it was not severe. The mixture used just before the leaf buds had opened was 6-4-50 Bordeaux, applied on May 5. Other fungicides used during the season were 5-5-50 Bordeaux mixture, Perdeux mixture,<sup>b</sup> Burgundy mix-

<sup>a</sup> These are commercial preparations generally obtainable.

<sup>b</sup> The composition of these mixtures is given on pages 11-13.

ture and 1 pound of resin-fishoil soap, and ammoniacal copper carbonate solution. Lead arsenate was also added for rootworms which were affecting the vineyard.

Seven applications of Bordeaux mixture were made on one plot, six on another, and four on another. Five applications of the Burgundy mixture and the ammoniacal copper carbonate solution were also tried.

The season was rather dry and unfavorable for the development of black-rot, so that there was no appreciable loss from this cause on the unsprayed check plot. There was, however, some injury from powdery mildew, which began to attack the foliage early in July, so that the principal benefit derived from the spraying was apparently due to the prevention of injury from this mildew. There was so little difference in the fruit of the different plots at picking time that it did not seem advisable to attempt to pick and sort separately the crop from each of the plots.

Plot 5, which had received four applications of 5-5-50 Bordeaux mixture, was picked and graded separately and compared with the fruit picked from the check plot. The check plot produced 2,195 4-pound baskets, and the sprayed plot 2,170 4-pound baskets. The principal profit apparently derived from spraying is indicated by the small quantity of culls or wine grapes present. On the check plot 15 per cent of the fruit consisted of culls, while on the sprayed plot there were only 8 per cent of culls. The fruit on the sprayed plot was also firmer and of much better keeping quality, according to the report of the buyer who packed and handled it. It will be noted, however, that on the check plot there were 25 baskets of fruit more than were on the sprayed plot. This was perhaps due to the fact that the check plot happened to contain some more vigorous and productive vines than the sprayed plot. This is always a source of some error in computing results. Even where the vines are of the same number and the same age there will always be some which are naturally more productive than others. The spraying outfit used in this work was a geared traction sprayer.

The following table shows the treatment of sprayed plot 5:

TABLE I.—*Treatment given plot 5 at North East, Pa., in 1906.*

Date of spraying.	Fungicide used.	Stage of growth.
June 8.....	5-5-50 Bordeaux mixture.....	Just before blooming.
June 26.....	5-5-50 Bordeaux mixture plus lead arsenate....	Berries all set.
July 9.....	5-5-50 Bordeaux mixture plus lead arsenate and soap.	Berries size of peas.
July 25.....	$\frac{1}{2}$ pound copper sulphate to 50 gallons of water...	Berries three-fourths grown.

## EXPERIMENTS IN 1907.

The work was continued in the same vineyard in 1907. The following fungicides were used: 5-5-50 Bordeaux mixture; 4-4-50 Bordeaux mixture; Burgundy mixture No. 1, plus 1 pound of resin-fishoil soap; Burgundy mixture No. 2, plus 1 pound of resin-fishoil soap; copper borate mixture No. 1; basic copper acetate solution, 5 ounces to 50 gallons of water; and copper chlorid mixture with 1 pound of resin-fishoil soap.

The first applications were made with a gasoline-engine outfit, as illustrated in figure 2. Subsequent applications were made with geared traction sprayers.

The weather conditions during 1907 were also dry and unfavorable for the development of black-rot, so that there was no loss from this cause on the check plot. There was, however, some injury from powdery mildew, as in 1906.

Plot 4 was selected for comparison with the check plot. This plot had been sprayed

with 4-4-50 Bordeaux mixture, with 2 pounds of resin-fishoil soap added for the first four applications. From the check plot 1,024 8-pound baskets were picked, and 1,220 8-pound baskets from sprayed plot 4. This shows an increase of 15 per cent of fruit on the sprayed plot. The percentage of culls, according to the report of the packers, was the same from each plot, and the additional quantity of fruit on the sprayed plot could not perhaps be justly attributed entirely to the effect of spraying. The same difference of productiveness of individual vines probably enters in this case as in that already referred to in 1906.



FIG. 2.—Gasoline-engine outfit used in spraying at North East, Pa., in 1907.

The following table shows the treatment of plot 4:

TABLE II.—*Treatment given plot 4 at North East, Pa., in 1907.*

Date of spraying.	Fungicide used.	Stage of growth.
June 15-17.....	4-4-50 Bordeaux mixture plus 2 pounds of soap..	Shoots 8 inches to 1 foot long.
July 9-10.....	do.....	Just before blooming.
July 20.....	4-4-50 Bordeaux mixture.....	Just after blooming.
August 9.....	Copper borate mixture.....	Berries three-fourths grown.

#### EXPERIMENTS IN 1908.

Work was continued in the same vineyard in 1908. The plots used covered four-fifths of an acre. Three applications each of the following mixtures were made: "A" brand concentrated lime-sulphur, 1 gallon to 50 gallons of water: Bordeaux mixture, 4-4-50, 4-3-50, and 3-2-50. The lime-sulphur burned the foliage and apparently can not be safely used in this strength on grapes. This opinion is also corroborated by the writers' experience in New York and Michigan.

This season, also, weather conditions were not favorable for the development of rot, and the benefit derived from the spraying consisted chiefly in the prevention of powdery mildew.

The yield from six of the plots was as follows:

TABLE III.—*Yield of grapes from six four-fifth-acre plots at North East, Pa., in 1908.*

No. of plot.	Fungicide used.	Yield, 8-pound baskets.
1	"A" brand lime-sulphur, 1 gallon to 50 gallons of water.....	432
2	4-4-50 Bordeaux mixture.....	554
3	4-3-50 Bordeaux mixture.....	479
4	4-2-50 Bordeaux mixture.....	479
5	3-2-50 Bordeaux mixture.....	430
6	Check, unsprayed.....	404
7	4-2-50 Bordeaux mixture.....	(*)
8	3-2-50 Bordeaux mixture.....	(*)

\* No record.

It will be noted that the largest amount of fruit (554 baskets) came from plot 2. All sprayed plots produced greater amounts of fruit than the check; the increase varied from 26 to 150 baskets. Here, again, it is probable that the difference in production of individual vines has affected the result, though there was a decided benefit to the vines on all of the sprayed plots, as shown by the healthy foliage, freedom from mildew, and the general vigor and thriftiness of the plants.



The following table shows the treatment of plot 2:

TABLE IV.—*Treatment given plot 2 at North East, Pa., in 1908.*

Date of spraying.	Fungicide used.	Stage of growth.
May 25.....	4-4-50 Bordeaux mixture plus 6 pounds of arsenate of lead.	Shoots 8 inches long.
June 17.....	4-4-50 Bordeaux mixture.....	Through blooming.
July 21.....	do.....	Berries about three-fourths grown.

From the point of view of the prevention of black-rot alone the experiments conducted at North East gave no important results, but it is believed that they have considerable significance on account of their bearing upon the question of the desirability of annual spraying as a regular practice and as a matter of insurance.

It is the belief of some of the best grape growers, as well as of the writers, that the spraying in this vineyard has proved profitable. Though the actual amount of profit each season in dollars and cents may not have been great, the general effect upon the vineyard is very noticeable when it is compared with other vineyards of about the same age which have been treated in about the same manner with the exception of spraying. The general health, vigor, and productiveness of the sprayed vineyard is very noticeable, and this condition can probably now be preserved with perhaps only three applications each season.

The so-called "dead-arm," or necrosis as it has been named by Reddick,<sup>a</sup> is a more serious matter in the Pennsylvania grape belt at present than black-rot. This disease has been under investigation for several years, but the work is not yet completed. Our experiments indicate that spraying alone is not likely to prove an effective means of controlling this trouble.

## WORK IN NEW YORK.

### EXPERIMENTS IN 1907.

The investigation of grape diseases, with spraying experiments, was commenced in the spring of 1907 in a large vineyard of Niagara grapes in charge of Mr. C. E. Smith at Kendaia, N. Y. The plots were 1 acre each, and the vines about 20 years old. The rows ran north and south. The vineyards in this region had suffered greatly from black-rot for several years and the growers had lost faith in the efficiency of the ordinary methods of preventing the disease. This work was

<sup>a</sup> Reddick, Donald. Necrosis of the Grapevine. Bulletin 263, Cornell University Agricultural Experiment Station. 1909.

part of a general plan for a thorough investigation of the grape diseases of the country and their control, and especially their relations to different varieties, soils, and climatic conditions. This locality afforded exceptional opportunities for the study of certain of the grape-disease problems, especially in their relation to the Niagara grape. An urgent invitation from the growers was accepted, and through an understanding with the Cornell University Agricultural Experiment Station the work was commenced. The results of the spraying experiments for the seasons of 1907 and 1908 are here given. The technical pathological investigations are not yet ready for publication.

The fungicides used were Bordeaux mixture, 5-5-50 and 4-4-50, with and without the addition of resin soap; Burgundy mixture, No. 1 and No. 2, and 1 pound of resin soap; copper borate mixture No. 1 and 1 pound of resin soap; normal copper acetate and one-half pound of resin soap; copper chlorid with 1 pound of resin soap. Wherever soap is mentioned the resin-fishoil soap, which was used as an adhesive, is meant.

Ten plots of 1 acre each were selected for the spraying experiments. Plot 7 was a check and received no treatment. The following table shows the treatment of the different plots:

TABLE V.—*Treatment given nine plots at Kendaia, N. Y., in 1907.*

PLOT 1.

Date of spraying.	Fungicide used.	Stage of growth.
May 10.....	6-3-50 Bordeaux mixture.....	Buds swelling.
May 22.....	5-5-50 Bordeaux mixture.....	Buds $\frac{3}{4}$ to 1 inch long.
June 11.....	do.....	Shoots 8 inches to 1 foot long.
June 28.....	do.....	Beginning to bloom.
July 13.....	do.....	Berries size of small peas.
July 25.....	do.....	Berries one-half grown.
August 2.....	do.....	Berries three-fourths grown.
August 13.....	Burgundy mixture No. 2.....	Berries grown.

PLOT 2.

May 10.....	6-3-50 Bordeaux mixture.....	Buds swelling.
May 22.....	4-4-50 Bordeaux mixture.....	Buds $\frac{3}{4}$ to 1 inch long.
June 11.....	do.....	Shoots 8 inches to 1 foot long.
June 28.....	do.....	Beginning to bloom.
July 13.....	do.....	Berries size of small peas.
July 25.....	do.....	Berries one-half grown.
August 2.....	do.....	Berries three-fourths grown.
August 13.....	Normal copper acetate.....	Berries grown.

PLOT 3.

May 10.....	6-3-50 Bordeaux mixture.....	Buds swelling.
May 21.....	4-4-50 Bordeaux mixture, with 2 pounds of soap.....	Buds $\frac{3}{4}$ to 1 inch long.
June 11.....	4-4-50 Bordeaux mixture.....	Shoots 8 inches to 1 foot long.
June 28.....	do.....	Beginning to bloom.
July 13.....	do.....	Berries size of small peas.
July 25.....	do.....	Berries one-half grown.
August 2.....	do.....	Berries three-fourths grown.
August 13.....	Copper borate only.....	Berries grown.

TABLE V.—*Treatment given nine plots at Kendaia, N. Y., in 1907—Continued.*

PLOT 4.		
Date of spraying.	Fungicide used.	Stage of growth.
May 10.....	6-3-50 Bordeaux mixture.....	Buds swelling.
May 22.....	Copper borate, with 2 pounds of soap.....	Buds $\frac{1}{2}$ to 1 inch long.
June 11.....	do.....	Shoots 8 inches to 1 foot long.
June 28.....	do.....	Beginning to bloom.
July 13.....	do.....	Berries size of small peas.
July 25.....	do.....	Berries one-half grown.
August 2.....	do.....	Berries three-fourths grown.
August 13.....	Copper borate only.....	Berries grown.
PLOT 5.		
May 10.....	6-3-50 Bordeaux mixture.....	Buds swelling.
May 22.....	Burgundy mixture No. 2.....	Buds $\frac{1}{2}$ to 1 inch long.
June 11.....	do.....	Shoots 8 inches to 1 foot long.
June 28.....	do.....	Beginning to bloom.
July 13.....	do.....	Berries size of small peas.
July 25.....	do.....	Berries one-half grown.
August 2.....	do.....	Berries three-fourths grown.
August 13.....	Burgundy mixture only.....	Berries grown.
PLOT 6.		
May 10.....	6-3-50 Bordeaux mixture.....	Buds swelling.
May 22.....	Copper chlorid mixture.....	Buds $\frac{1}{2}$ to 1 inch long.
June 11.....	do.....	Shoots 8 inches to 1 foot long.
June 28.....	do.....	Beginning to bloom.
July 13.....	do.....	Berries size of small peas.
July 25.....	do.....	Berries one-half grown.
August 2.....	do.....	Berries three-fourths grown.
August 13.....	do.....	Berries grown.
PLOT 8.		
June 11.....	5-5-50 Bordeaux mixture.....	Shoots 8 inches to 1 foot long.
June 28.....	do.....	Beginning to bloom.
July 13.....	do.....	Berries size of small peas.
July 25.....	do.....	Berries one-half grown.
August 2.....	do.....	Berries three-fourths grown.
PLOT 9.		
June 11.....	4-4-50 Bordeaux mixture and 2 pounds of soap.....	Shoots 8 inches to 1 foot long.
June 28.....	do.....	Beginning to bloom.
July 13.....	do.....	Berries size of small peas.
July 25.....	do.....	Berries one-half grown.
August 2.....	4-4-50 Bordeaux mixture.....	Berries three-fourths grown.
PLOT 10.		
June 11.....	Copper borate mixture.....	Shoots 8 inches to 1 foot long.
June 28.....	do.....	Beginning to bloom.
July 13.....	do.....	Berries size of small peas.
July 25.....	do.....	Berries one-half grown.
August 2.....	do.....	Berries three-fourths grown.
August 13.....	Normal copper acetate.....	Berries grown.

The weather conditions during the season were not so favorable for the development of rot as they had been the year previous. On the unsprayed check plot the first indications of disease were found, as shown by spots on the leaves, on July 11. There was an outbreak of rot on the fruit and foliage from July 22 to July 25. The total amount of rot on the check before picking was 23.8 per cent.

The following table shows the results of the applications to the different plots:

TABLE VI.—Results of spraying experiments on nine plots of Niagara grapes at Kendaia, N. Y., in 1907.

No. of plot.	Number of applications given.	Fungicide used.	Rot.
1	8	5-5-50 Bordeaux mixture, and Burgundy mixture No. 2 for last application.	Per cent.* 8.8
2	8	4-4-50 Bordeaux mixture, and normal copper acetate and one-half pound of soap for last application.	8.0
3	8	4-4-50 Bordeaux mixture plus 2 pounds of soap, and copper borate No. 1 and 1 pound of soap for last application.	6.2
4	8	Copper borate mixture No. 1 and 1 pound of soap	10.1
5	8	Burgundy mixture No. 2 and 1 pound of soap	11.4
6	8	Copper chlorid mixture and 1 pound of soap	12.8
7	8	Check, unsprayed	23.8
8	5	5-5-50 Bordeaux mixture	6.3
9	5	4-4-50 Bordeaux mixture and soap	7.2
10	6	Copper borate and 1 pound of soap, and normal copper acetate for last application.	8.3
		Ordinary spraying with Bordeaux mixture as heretofore practiced in the vineyard.	12.072

\* Determined by count of rotten berries.

The percentages of rot given were determined by an actual count of the diseased berries found on 2,500 clusters from vines showing the average condition of the plot and by comparing this number with the average number of berries usually produced upon the same number of clusters. (See Pl. I, figs. 1 and 2.)

It will be noted that Bordeaux mixture gave the best results and that five applications proved just about as effective as eight. There was scarcely any difference in the results from the use of the 5-5-50 and the 4-4-50 formulas. There was 2 per cent less rot on plot 3 than on plots 1 and 2, apparently attributable to the addition of the resin soap, but in other cases the benefit from this was not evident.

#### EXPERIMENTS IN 1908.

The work in New York was continued in the season of 1908 in the same vineyard and on the same vines used in 1907, but the plots were reduced to five-sixths of an acre each.

The following fungicides were used:

Bordeaux mixture, 4-4-50, 4-3-50, and 3-2-50 formulas.

Copper borate mixture No. 3.

Neutral copper acetate solution. This was used chiefly as a nonstaining preparation for final applications.

Self-boiled lime-sulphur, prepared with hot water.

"A" brand concentrated lime-sulphur solution, 1 gallon to 50 gallons of water; also 1 gallon to 75 gallons of water.

Resin-fishoil soap was also added in some cases, as indicated in the tables which follow.

The spraying was done, as in the preceding season, with a gasoline-engine outfit. Stationary nozzles were used for the earlier applica-





FIG. 1.—PORTION OF A NIAGARA VINE WITH THE LEAVES REMOVED, SHOWING SPRAYED FRUIT, KENDAIA, N. Y., 1907.



FIG. 2.—PORTION OF AN UNSPRAYED NIAGARA VINE WITH THE LEAVES REMOVED, FROM CHECK PLOT, KENDAIA, N. Y., 1907.



tions, and three fixed nozzles and trailers with two nozzles each directed by hand were used for the fifth and sixth applications. Plot 7 was a check and received no treatment.

The following table shows the treatment given each of the plots:

TABLE VII.—*Treatment given ten plots at Kendaia, N. Y., in 1908.*

PLOT 1.

Date of spraying.	Fungicide used.	Stage of growth.
June 1.....	4-4-50 Bordeaux mixture.....	Shoots 10 inches to 1 foot long.
June 12.....	do.....	Just beginning to bloom.
June 26.....	do.....	Through blooming.
July 8-9.....	do.....	Berries one-third grown.
July 23.....	do.....	Berries one-half grown.
August 12.....	Neutral copper acetate.....	Berries nearly grown.

PLOT 2.

June 1.....	4-3-50 Bordeaux mixture.....	Shoots 10 inches to 1 foot long.
June 12.....	do.....	Just beginning to bloom.
June 26.....	do.....	Through blooming.
July 8.....	do.....	Berries one-third grown.
July 23.....	do.....	Berries one-half grown.
August 12.....	Neutral copper acetate.....	Berries nearly grown.

PLOT 3.

June 1.....	4-2-50 Bordeaux mixture.....	Shoots 10 inches to 1 foot long.
June 12.....	do.....	Just beginning to bloom.
June 26.....	do.....	Through blooming.
July 8.....	do.....	Berries one-third grown.
July 23.....	do.....	Berries one-half grown.
August 12.....	Neutral copper acetate.....	Berries nearly grown.

PLOT 4.

June 1.....	3-2-50 Bordeaux mixture.....	Shoots 10 inches to 1 foot long.
June 12.....	do.....	Just beginning to bloom.
June 26.....	do.....	Through blooming.
July 8.....	do.....	Berries one-third grown.
July 23.....	do.....	Berries one-half grown.
August 12.....	Neutral copper acetate.....	Berries nearly grown.

PLOT 5.

June 1.....	4-2-50 Bordeaux mixture, with 2 pounds of soap.....	Shoots 10 inches to 1 foot long.
June 12.....	do.....	Just beginning to bloom.
June 26.....	do.....	Through blooming.
July 8.....	do.....	Berries one-third grown.
July 23.....	4-2-50 Bordeaux mixture.....	Berries one-half grown.
August 12.....	Neutral copper acetate.....	Berries nearly grown.

PLOT 6.

June 1.....	3-2-50 Bordeaux mixture, with 2 pounds of soap.....	Shoots 10 inches to 1 foot long.
June 12.....	do.....	Just beginning to bloom.
June 26.....	do.....	Through blooming.
July 8.....	do.....	Berries one-third grown.
July 23.....	3-2-50 Bordeaux mixture.....	Berries one-half grown.
August 12.....	Neutral copper acetate.....	Berries nearly grown.

PLOT 8.

June 12.....	4-3-50 Bordeaux mixture.....	Just beginning to bloom.
June 26.....	Copper borate No. 3, with 1 pound of soap.....	Through blooming.
July 9.....	do.....	Berries one-third grown.
July 23.....	Copper borate.....	Berries one-half grown.
August 12.....	do.....	Berries nearly grown.

TABLE VII.—*Treatment given ten plots at Kendaia, N. Y., in 1908—Continued.*

PLOT 9.		
Date of spraying.	Fungicide used.	Stage of growth.
June 12.....	4-3-50 Bordeaux mixture.....	Just beginning to bloom.
June 26.....	Neutral copper acetate.....	Through blooming.
July 9.....	do.....	Berries one-third grown.
July 23.....	do.....	Berries one-half grown.
August 12.....	do.....	Berries nearly grown.

PLOT 10.		
June 12.....	4-3-50 Bordeaux mixture.....	Just beginning to bloom.
June 26.....	Self-boiled lime-sulphur No. 1, 8-15-50.....	Through blooming.
July 9.....	do.....	Berries one-third grown.
July 23.....	Self-boiled lime-sulphur No. 2, 10-15-50.....	Berries one-half grown.
August 12.....	"A" brand lime-sulphur No. 2, 1 gallon to 75 gallons of water.	Berries nearly grown.

PLOT 11.		
June 12.....	4-3-50 Bordeaux mixture.....	Just beginning to bloom.
June 26.....	"A" brand lime-sulphur No. 1, 1 gallon to 50 gallons of water.	Through blooming.
July 9.....	do.....	Berries one-third grown.
July 23.....	do.....	Berries one-half grown.
August 12.....	"A" brand lime-sulphur No. 2, 1 gallon to 75 gallons of water.	Berries nearly grown.

The plot which had been used as a check in 1907 was sprayed this season. The first signs of disease were noted on June 25, when spots caused by the black-rot fungus began to appear on the leaves.

The following table shows the results of the treatment of the different plots:

TABLE VIII.—*Results of spraying experiments on ten plots of Niagara grapes at Kendaia, N. Y., in 1908.*

No. of plot.	Number of applications.	Fungicide used.	Rot.	Yield of select market grapes.	Yield of wine grapes.
			Per cent.*	Baskets (4 lb.).	Baskets (20 lb.).
1	6	4-4-50 Bordeaux mixture†.....	1.9	758	157
2	6	4-3-50 Bordeaux mixture.....	1.06	800	131
3	6	4-2-50 Bordeaux mixture.....	.79	610	136½
4	6	3-2-50 Bordeaux mixture.....	.79	608	142½
5	6	4-2-50 Bordeaux mixture and 2 pounds of resin-fishoil soap.....	.49	523	148
6	6	3-2-50 Bordeaux mixture and 2 pounds of resin-fishoil soap.....	1.6	696	160
7		Check, unsprayed.....	17.44	505	112
8	5	4-3-50 Bordeaux mixture, first application only. Following applications, copper borate No. 3, with 1 pound of soap.....	3.48	957	145
9	5	4-3-50 Bordeaux mixture, first application only. Following applications, neutral copper acetate, 1 pound to 50 gallons of water.....	1.01	685	105
10	5	4-3-50 Bordeaux mixture, first application only. Following applications, self-boiled lime-sulphur Nos. 1 and 2.....	1.1	319	150
11	5	4-3-50 Bordeaux mixture, first application only. Following applications, "A" brand lime-sulphur Nos. 1 and 2.....	.37	863	115

\* Determined by count of rotten berries.

† Neutral copper acetate used in last spraying on plots 1 to 6, inclusive; also on plot 9.

From this table it will be noted that the smallest percentage of rot, as determined by counting the diseased berries, was upon plot 11, which was sprayed first with 4-3-50 Bordeaux mixture, followed



by three applications of "A" brand concentrated lime-sulphur solution, one gallon to 50 of water, and a final application of 1 gallon of the same material to 75 of water. It was intended to treat this plot throughout the season with the concentrated lime-sulphur solution, but the material was not received in time to be used for the first application. The concentrated lime-sulphur solution, when used at the rate of 1 gallon to 50 of water, caused such severe injury to the foliage that for the final application it was reduced to 1 to 75. Hence, from the facts that this plot was not treated with the concentrated lime-sulphur solution alone, and that the injury to the foliage was so great as to preclude its future use in the same strength, the results do not justify positive conclusions in regard to either the efficiency or the practicability of using this preparation for black-rot. It remains to be determined whether this concentrated lime-sulphur can be diluted sufficiently to avoid injury to the foliage and still retain the necessary fungicidal properties. The plot treated with self-boiled lime-sulphur was also sprayed the first time with Bordeaux mixture, and as the lime-sulphur was made by the use of hot water it also caused some injury to the foliage. The fruit was also rather badly stained by the self-boiled lime-sulphur solutions.

The yield in select market grapes and wine grapes is also given. The yield from the various plots does not always bear a direct relation to the treatment and to the amount of rot present, as the number of vines in the rows varied somewhat and there was also some variation in the vigor and productiveness of the individual vines.

The following is an itemized statement of the expenses connected with the spraying and shows also the returns from the fruit and the gain per acre due to spraying:

*Cost of spraying plot 2, five-sixths of an acre, at Kendaia, N. Y., in 1908, returns from plot 2, and returns from the five-sixths-acre unsprayed plot.*

Plot No. 2 (sprayed):

800 4-pound baskets, at 12 cents.....	\$96. 00
131 20-pound baskets, at 30 cents.....	39. 30
Total receipts.....	135. 30
Man, team, and sprayer, each application.....	\$0. 35
Bluestone, 8 pounds, at 6 cents; lime, 6 pounds, at five-ninths cent.....	. 51½
One application of Bordeaux mixture, 4-3-50.....	. 86½
Five applications of Bordeaux mixture, 4-3-50, at 86½ cents.....	4. 32
Resin-fishoil soap, 3 applications, 12 pounds, at 3½ cents.....	. 42
One additional application of copper acetate, 2 pounds, at 45 cents, plus 35 cents for application.....	1. 25
Extra help handling trailers, two applications.....	. 60
Packing.....	7. 75
Total, six applications.....	14. 34
Net receipts.....	\$120. 96

Net receipts, brought forward.....	\$120.96
Plot No. 7 (unsprayed):	
505 4-pound baskets, at 12 cents.....	\$60.60
112 20-pound baskets, at 30 cents.....	33.60
Total receipts.....	94.20
Packing.....	16.00
Net receipts.....	78.20
Gain from spraying five-sixths of an acre.....	42.76
Gain per acre at same rate.....	<sup>a</sup> 51.31

#### WORK IN MICHIGAN.

The principal grape-growing district in Michigan is located in the southwestern part of the State, Paw Paw and Lawton being the principal centers. Until a few years ago fungous diseases had not caused any very serious losses in this region. As is usually the case, it was only after grapes had been grown for a number of years and the vineyards had become quite extensive and numerous that the diseases began to be very serious. For two or three seasons previous to 1907 many of the grape growers suffered severe loss from fungous troubles, especially black-rot. This was apparently due to a combination of circumstances. The fungi causing the diseases had had sufficient time to become thoroughly established and distributed, and under the very favorable climatic conditions which prevailed—excessive heat and moisture during the growing season—proved very destructive.

Most of the growers had had no practical experience in spraying and were hoping that the troubles were of a more or less temporary character, and would perhaps soon pass away. This did not, however, prove to be the case, and during the seasons of 1906 and 1907 the losses were so general and so great that many growers were becoming disheartened. At the time the writers began work in this region few spraying outfits were in use. Some spraying had already been done there under the direction of Professor Taft, of the Michigan Agricultural Experiment Station, but few of the growers had taken up the work. The work of the Bureau of Plant Industry was undertaken in accordance with an understanding with the director of the Michigan Agricultural Experiment Station. The spraying experiments have received continuous personal direction and supervision in every detail throughout each season, and advice and assistance have been given growers whenever desired. The chief purposes of the spraying experiments were to make a comparative test of fungicides and to determine the most efficient methods of treatment under the prevailing climatic and cultural conditions, and incidentally to demon-

<sup>a</sup> Six hundred gallons of Bordeaux mixture were used for the six applications on the five-sixths acre. Ordinarily this amount would be sufficient for an acre, and the gain would thus be increased to \$52.62.



FIG. 1.—CARBONIC-ACID-GAS SPRAYER USED IN SPRAYING EXPERIMENTS IN 1907 AND 1908 IN THE VINEYARD OF MRS. EMMA R. SMITH, PAW PAW, MICH.



FIG. 2.—MIXING PLATFORM AND GEARED TRACTION SPRAYER USED IN SPRAYING EXPERIMENTS IN THE VINEYARD OF MR. J. M. TOWERS, PAW PAW, MICH., IN 1908.





strate the practicability of controlling black-rot even in the case of a very severe epidemic.

In 1906, so far as the writers could learn, but six sprayers were in use in the Lawton grape belt. Interest in spraying and confidence in its results have so increased that most of the growers have secured sprayers and are in nearly all cases satisfactorily controlling the black-rot. In the summer of 1908 at least two hundred spraying outfits were found in use, and perhaps there were others of which the writers did not learn. Thirteen different kinds were represented.

#### EXPERIMENTS IN 1907.

The work of 1907 was commenced in two vineyards in the vicinity of Paw Paw, but in one vineyard, that of Mr. J. M. Towers, it was discontinued on account of partial loss of the crop by frost and insects.

The work in the other vineyard, that of Mrs. Emma R. Smith, was continued throughout the season. This vineyard consisted of Concord vines about 25 years old, trained after the Kniffin system, with the rows running north and south. The fruit the previous season had been almost totally destroyed by rot. Four plots adjoining each other were selected. The three sprayed plots contained about 0.46 acre each, and the check 0.115 acre.

The fungicides used were as follows: 3-50 copper sulphate solution; 5-5-50 Bordeaux mixture; 4-4-50 Bordeaux mixture; 3-3-50 Bordeaux mixture. For the sixth and seventh applications, Burgundy mixture No. 2 was used in order to avoid too much staining of the fruit. The work was done with a carbonic-acid-gas sprayer. (See Pl. II, fig. 1.) The first applications were made with fixed nozzles, and the last three with trailers, the nozzles being directed by hand. In order to determine the percentage of rot present on the different plots, counts of the sound and the diseased grapes were made between September 23 and October 2, 1,000 bunches from each of the sprayed plots and 100 from the check being taken. The check, which received no treatment, was plot 3.

The following table shows the treatment of each plot:

TABLE IX.—*Treatment given three plots in Mrs. Smith's vineyard, near Paw Paw, Mich., in 1907.*

PLOT 1.

Date of spraying.	Fungicide used.	Stage of growth.
May 5.....	3-50 copper sulphate solution.....	Dormant.
June 20.....	3-3-50 Bordeaux mixture.....	Just beginning to blossom.
July 6.....	do.....	Just after blossoming.
July 16.....	do.....	Grapes about size of peas.
July 23.....	3 3 50 Bordeaux mixture, with 2 pounds of soap.	Grapes about one-third grown.
August 2.....	Burgundy mixture No. 2.....	Grapes about one-half grown.
August 15.....	do.....	Grapes about three-fourths grown.

TABLE IX.—*Treatment given three plots in Mrs. Smith's vineyard, near Paw Paw, Mich., in 1907—Continued.*

## PLOT 2.

Date of spraying.	Fungicide used.	Stage of growth.
May 5.....	3-50 copper sulphate solution.....	Dormant.
June 20.....	4-4-50 Bordeaux mixture.....	Just beginning to blossom.
July 6.....	do.....	Just after blossoming.
July 16.....	do.....	Grapes about size of peas.
July 23.....	4-4-50 Bordeaux mixture, with 2 pounds of soap.	Grapes about one-third grown.
August 2.....	Burgundy mixture No. 2.....	Grapes about one-half grown.
August 15.....	do.....	Grapes about three-fourths grown.

## PLOT 4.

May 5.....	3-50 copper sulphate solution.....	Dormant.
June 20.....	5-5-50 Bordeaux mixture.....	Just beginning to blossom.
July 6.....	do.....	Just after blossoming.
July 16.....	do.....	Grapes about size of peas.
July 23.....	do.....	Grapes about one-third grown.
August 2.....	Burgundy mixture No. 2.....	Grapes about one-half grown.
August 15.....	do.....	Grapes about three-fourths grown.

The amount of rot on the plots at the close of the season was determined by actual count of the number of sound and affected berries on 1,000 average bunches from each plot, as already stated.

Just across a roadway at the south end of this vineyard was another which was very severely injured by black-rot; in fact, most of the crop was destroyed before the fruit was much over half grown. In order to get some idea of the effect of this apparently serious source of infection upon the portions of the experimental plots nearest to this vineyard, counts were made of the affected grapes at both ends of the rows, those adjoining the neglected vineyard and those farthest from it.

The following table shows the percentage of rot at both ends of each plot, and also the difference between the two ends:

TABLE X.—*Comparison of the amount of rot on the ends of plots adjoining and those farthest from an unsprayed vineyard near Paw Paw, Mich., 1907.*

No. of plot.	Fungicide used.	Rot.		
		South end.*	North end.†	Difference.
		Per cent.	Per cent.	Per cent.
1	Bordeaux mixture, 3-3-50.....	56.4	31.2	25.2
2	Bordeaux mixture, 4-4-50.....	34.9	23.8	11.1
3	Check, no treatment.....	91.7	86.1	5.6
4	Bordeaux mixture, 5-5-50.....	32.7	23.1	9.6

\* Adjoining unsprayed vineyard severely affected with black-rot.

† Farthest from unsprayed vineyard.



FIG. 1.—PART OF A CONCORD VINE SPRAYED WITH 5-5-50 BORDEAUX MIXTURE, MRS. SMITH'S VINEYARD, PAW PAW, MICH. PHOTOGRAPHED SEPTEMBER 8, 1907.



FIG. 2.—CONCORD VINE FROM UNSPRAYED AND NEGLECTED VINEYARD IN THE SAME NEIGHBORHOOD AND PHOTOGRAPHED ON THE SAME DAY AS THE VINE SHOWN IN FIGURE 1. THE CROP WAS ENTIRELY DESTROYED AND THE VINE NEARLY DEFOLIATED BY BLACK-ROT.



The average percentage of rot for the four plots is as follows:

TABLE XI.—Results of spraying experiments on three plots of Concord grapes near Paw Paw, Mich., in 1907.

No. of plot.	Number of applications.	Fungicide used.	Rot.
			<i>Per cent.*</i>
1	7	3-3-50 Bordeaux mixture †.....	43.7
2	7	4-4-50 Bordeaux mixture.....	28.7
3	—	Check, unsprayed.....	89.2
4	7	5-5-50 Bordeaux mixture.....	28.3

\* Determined by count of rotten berries.

† Soap was used in fifth spraying on plots 1 and 2 and Burgundy mixture No. 2 for the sixth and seventh sprayings on all plots.

Although only 89.2 per cent of the fruit on the unsprayed plot was found by actual count to be destroyed, it was not considered practicable to try to harvest any of it because the expense of separating the small quantity of sound fruit would have been much more than its value. The crop on the unsprayed plot was therefore practically a total loss. It will be noted that there was scarcely any difference in the amount of rot on the plot sprayed with 4-4-50 and on that sprayed with 5-5-50 Bordeaux mixture. Part of a vine from the latter plot and a typical vine from a neighboring neglected vineyard are shown in Plate III. On the neglected vine the fruit was not only completely destroyed, but the plant was defoliated and thus prevented from properly maturing the season's growth of wood.

The following itemized account shows the gain due to spraying on plot 2 (five applications with 4-4-50 Bordeaux mixture and two with Burgundy mixture, or 475 gallons in all, on 0.46 acre) and the corresponding gain per acre estimated upon the same basis:

*Receipts and expenditures, plot 2, Paw Paw, Mich., 1907.*

2,010 pounds grapes, at \$40 a ton.....	<sup>a</sup> \$40. 20
Man and team to spray, 8½ hours, at 35 cents.....	\$3. 06
Man and horse to haul mixture, 8½ hours, at 25 cents.....	2. 19
Two men to carry trailers for last three sprayings, 5½ hours, at 15 cents an hour each.....	1. 58
Two-thirds tube of gas, at \$2.35.....	1. 57
Copper sulphate, 26 pounds, at 8½ cents.....	2. 28
Resin-fishoil soap, 11 pounds, at 3½ cents.....	. 39
Sal soda, 6 pounds, at 3 cents.....	. 18
Total cost of spraying plot, 0.46 acre.....	11. 25
Gain from spraying on 0.46 acre.....	28. 95
Gain per acre at same rate.....	62. 93

<sup>a</sup> As no fruit was harvested on the unsprayed plot at Paw Paw, Mich., in 1907, this amount is all attributed to spraying.



## EXPERIMENTS IN 1908.

The work in 1908 was carried on in three different vineyards: Mrs. Emma Smith's, as already described; Mr. J. M. Towers's, near Paw Paw; and Mr. C. C. Giddings's vineyard, near Lawton. The work in Mrs. Smith's vineyard was conducted on the same plots used in 1907 and with the same spraying outfit and, as before, trailers with nozzles directed by hand instead of fixed nozzles were used for the last three sprayings. It was found that in order to satisfactorily cover the foliage and fruit at the time of the later applications the nozzles, or part of them at least, must be thus manipulated.

## EXPERIMENTS IN MRS. SMITH'S VINEYARD, NEAR PAW PAW, MICH.

The treatment given the different plots in Mrs. Smith's vineyard is shown in the following table. Plot 2 was a check and received no treatment.

TABLE XII.—*Treatment given three plots in Mrs. Smith's vineyard, near Paw Paw, Mich., in 1908.*

## PLOT 1.

Date of spraying.	Fungicide used.	Stage of growth.
May 19.....	4-4-50 Bordeaux mixture.....	Shoots about 6 inches long.
May 29.....	do.....	Shoots 18 to 24 inches long.
June 2.....	do.....	Shoots 20 to 28 inches long.
June 15.....	do.....	Just after blooming.
June 24.....	do.....	Grapes about the size of peas.
July 3.....	do.....	Grapes about one-half grown.
July 22.....	4-2-50 Bordeaux mixture.....	Grapes about four-fifths grown.

## PLOT 3.

May 19.....	4-3-50 Bordeaux mixture.....	Shoots about 6 inches long.
May 29.....	do.....	Shoots 18 to 24 inches long.
June 2.....	do.....	Shoots 20 to 28 inches long.
June 15.....	do.....	Just after blooming.
June 24.....	do.....	Grapes about the size of peas.
July 3.....	do.....	Grapes about one-half grown.
July 6.....	do.....	Grapes about one-half grown.
July 22.....	4-2-50 Bordeaux mixture.....	Grapes about four-fifths grown.

## PLOT 4.

May 19.....	4-2-50 Bordeaux mixture.....	Shoots about 6 inches long.
May 29.....	do.....	Shoots 18 to 24 inches long.
June 2.....	do.....	Shoots 20 to 28 inches long.
June 15.....	do.....	Just after blooming.
June 24.....	do.....	Grapes about the size of peas.
July 6.....	do.....	Grapes about one-half grown.
July 22.....	do.....	Grapes about four-fifths grown.

The following table shows the percentage of rot as determined by actual count, as in the preceding season's work:

TABLE XIII.—*Results of spraying experiments on three plots of Concord grapes in Mrs. Smith's vineyard, near Paw Paw, Mich., in 1908.*

No. of plot.	Number of applications.	Fungicide used.	Rot.
			<i>Per cent.</i>
1.....	7	4-4-50 Bordeaux mixture.....	0.197
2.....		Check, unsprayed (but sprayed in 1907).....	17.257
3.....	8	4-3-50 Bordeaux mixture.....	.034
4.....	7	4-2-50 Bordeaux mixture.....	.178

The small amount of rot on the check plot was believed to be largely due to the fact that this plot was sprayed in the season of 1907. It would have been better, perhaps, for purposes of comparison, to have used the same check as in 1907. As the amount of rot in a neglected vineyard near by was as great in 1908 as in the previous year, there seems to be no reason to suppose that the rot on this unsprayed plot would not have been about as great also, except for the treatment given it in 1907.

It will be noted that in this experiment the plots sprayed with 4-3-50 Bordeaux mixture showed the least amount of rot. The very small percentage of rot on all the plots illustrates very clearly what may perhaps be called the cumulative effect of spraying. The disease having been largely brought under control the first season can generally be much more easily handled during succeeding seasons.

The following is an itemized account of the work, showing the gain on plot 3, 0.46 acre, which received seven sprayings with 4-3-50 Bordeaux mixture and one with 4-2-50, 500 gallons in all:

*Receipts and expenditures, plot 3, Mrs. Smith's vineyard, near Paw Paw, Mich., 1908.*

Yield from plot 3, sprayed, 660 8-pound baskets, at 11.66 cents.....	\$76.96	
Receipts per acre at same rate.....		\$167.30
Yield from check plot, 1,134.75 pounds, at \$20.64 a ton.....	11.71	
Receipts per acre at same rate.....		101.83
Gain per acre due to spraying .....		65.47
Man and team to spray, 10 hours, at 35 cents.....	\$3.50	
Man and horse to haul mixture, 10 hours, at 25 cents.....	2.50	
Two men to carry trailers for last four sprayings, 6 hours, at 15 cents an hour each.....	1.80	
Copper sulphate, 40 pounds, at 6½ cents.....	2.70	
Stone lime, 30 pounds, at two-thirds of a cent.....	.20	
Five-sevenths tube of gas, at \$2.35.....	1.68	
Total cost of spraying plot, 0.46 acre.....	12.38	
Cost of spraying 1 acre at same rate.....		26.91
Net gain per acre due to spraying.....		\$ 38.56

<sup>a</sup> Grapes in same vineyard sprayed five times showed no appreciable difference in amount of rot. Difference in net gain this year was due to extra sprayings and to less loss on check as result of previous treatment (1907).

## EXPERIMENTS IN MR. TOWERS'S VINEYARD, NEAR PAW PAW, MICH.

In 1908 spraying experiments were again started in Mr. J. M. Towers's vineyard, near Paw Paw. This vineyard consisted of Concord vines about 8 years old, with the rows running north and south. Nine plots, 0.488 acre each, as nearly uniform in character and condition as possible, were selected. The work was done with the geared traction sprayer shown in Plate II, figure 2. The mixing platform used is also shown in the same figure.

The following fungicides were used: Bordeaux mixture, 4-4-50, 4-3-50, 4-2-50, 5-5-50, 5-4-50, and 5-3-50; also sodium benzoate Bordeaux mixtures Nos. 1 and 2. Six applications were made, as shown in the accompanying tables, the last one consisting of 4-2-50 Bordeaux mixture. Plot 4 was a check and received no treatment.

TABLE XIV.—*Treatment given eight plots in Mr. Towers's vineyard, near Paw Paw, Mich., in 1908.*

## PLOT 1.

Date of spraying.	Fungicide used.	Stage of growth.
May 20.....	4-4-50 Bordeaux mixture.....	Shoots about 8 inches long.
May 30.....	do.....	Shoots 16 to 20 inches long.
June 17.....	do.....	Just after blossoming.
June 29.....	do.....	Grapes the size of peas.
July 13.....	do.....	Grapes about three-fourths grown.
July 25.....	4-2-50 Bordeaux mixture.....	Grapes nearly full grown.

## PLOT 2.

May 20.....	4-3-50 Bordeaux mixture.....	Shoots about 8 inches long.
May 30.....	do.....	Shoots 16 to 20 inches long.
June 17.....	do.....	Just after blossoming.
June 29.....	do.....	Grapes the size of peas.
July 13.....	do.....	Grapes about three-fourths grown.
July 25.....	4-2-50 Bordeaux mixture.....	Grapes nearly full grown.

## PLOT 3.

May 20.....	4-2-50 Bordeaux mixture.....	Shoots about 8 inches long.
May 30.....	do.....	Shoots 16 to 20 inches long.
June 17.....	do.....	Just after blossoming.
June 30.....	do.....	Grapes the size of peas.
July 13.....	do.....	Grapes about three-fourths grown.
July 25.....	do.....	Grapes nearly full grown.

## PLOT 5.

May 20.....	5-5-50 Bordeaux mixture.....	Shoots about 8 inches long.
May 30.....	do.....	Shoots 16 to 20 inches long.
June 17.....	do.....	Just after blossoming.
June 30.....	do.....	Grapes the size of peas.
July 13.....	do.....	Grapes about three-fourths grown.
July 25.....	4-2-50 Bordeaux mixture.....	Grapes nearly full grown.

## PLOT 6.

May 20.....	5-4-50 Bordeaux mixture.....	Shoots about 8 inches long.
May 30.....	do.....	Shoots 16 to 20 inches long.
June 17.....	do.....	Just after blossoming.
June 30.....	do.....	Grapes the size of peas.
July 13.....	do.....	Grapes about three-fourths grown.
July 25.....	4-2-50 Bordeaux mixture.....	Grapes nearly full grown.

TABLE XIV.—*Treatment given eight plots in Mr. Towers's vineyard, near Paw Paw, Mich., in 1908—Continued.*

## PLOT 7.

Date of spraying.	Fungicide used.	Stage of growth.
May 20.....	5-3-50 Bordeaux mixture.....	Shoots about 8 inches long.
June 1.....	do.....	Shoots 16 to 20 inches long.
June 17.....	do.....	Just after blossoming.
June 30.....	do.....	Grapes the size of peas.
July 13.....	do.....	Grapes about three-fourths grown.
July 25.....	4-2-50 Bordeaux mixture.....	Grapes nearly full grown.

## PLOT 8.

May 20.....	Sodium benzoate Bordeaux mixture No. 2, 1-1-1-50.	Shoots about 8 inches long.
June 1.....	do.....	Shoots 16 to 20 inches long.
June 18.....	do.....	Just after blossoming.
June 30.....	do.....	Grapes the size of peas.
July 14.....	do.....	Grapes about three-fourths grown.
July 25.....	4-2-50 Bordeaux mixture.....	Grapes nearly full grown.

## PLOT 9.

May 20.....	Sodium benzoate Bordeaux mixture No. 1, 2-1-1-50.	Shoots about 8 inches long.
June 1.....	do.....	Shoots 16 to 20 inches long.
June 18.....	do.....	Just after blossoming.
June 30.....	do.....	Grapes the size of peas.
July 14.....	do.....	Grapes about three-fourths grown.
July 25.....	4-2-50 Bordeaux mixture.....	Grapes nearly full grown.

The results of these experiments are shown in the following table:

TABLE XV.—*Results of spraying experiments on eight plots of Concord grapes in Mr. Towers's vineyard, near Paw Paw, Mich., in 1908.*

No. of plot.	Number of applications.	Fungicide used.	Rot.
			Percent.*
1.....	6	4-4-50 Bordeaux mixture, first five applications†.....	0.03
2.....	6	4-3-50 Bordeaux mixture, first five applications.....	0.097
3.....	6	4-2-50 Bordeaux mixture.....	0.042
4.....		Check, unsprayed.....	7.36
5.....	6	5-5-50 Bordeaux mixture, first five applications.....	0.051
6.....	6	5-4-50 Bordeaux mixture, first five applications.....	0.07
7.....	6	5-3-50 Bordeaux mixture, first five applications.....	0.064
8.....	6	Sodium benzoate Bordeaux mixture No. 2.....	0.083
9.....	6	Sodium benzoate Bordeaux mixture No. 1.....	0.127

\* Determined by count of rotten grapes.

† Bordeaux mixture 4-2-50 was used in sixth spraying on all plots.

The percentages of rot given were obtained by actual count of the rotten grapes on clusters showing the average condition of each plot, as in the other cases. It will be noted that the smallest percentage of rot was found on plot 1, treated with 4-4-50 Bordeaux mixture. The difference in amount of rot, however, on the various plots was so slight in most cases as to give no very decided indication of the comparative value of the different mixtures. The amount of rot on the check plot was also small.

## EXPERIMENTS IN MR. GIDDINGS'S VINEYARD, NEAR LAWTON, MICH.

Mr. Giddings's vineyard consisted of Concord vines about 14 years old. Eleven plots of one-third acre each were used in the experiments.

The work was done with a geared traction sprayer, fixed nozzles being used for the first three applications, and trailers, with the nozzles directed by hand, for the last three applications. Plot 5 was a check and was not sprayed.

The following table shows the treatment given each plot:

TABLE XVI.—*Treatment given ten plots in Mr. Giddings's vineyard, near Lawton, Mich., in 1908.*

PLOT 1.

Date of spraying.	Fungicide used.	Stage of growth.
May 21.....	4-4-50 Bordeaux mixture.....	Shoots about 8 inches long.
June 2.....	.....do.....	Shoots about 18 to 24 inches long.
June 15.....	.....do.....	Just after blossoming.
June 25.....	.....do.....	Grapes the size of peas.
July 8.....	.....do.....	Grapes about one-half grown.
July 23.....	4-2-50 Bordeaux mixture.....	Grapes nearly full grown.

PLOT 2.

May 21.....	4-3-50 Bordeaux mixture.....	Shoots about 8 inches long.
June 2.....	.....do.....	Shoots 18 to 24 inches long.
June 15.....	.....do.....	Just after blossoming.
June 25.....	.....do.....	Grapes the size of peas.
July 8.....	.....do.....	Grapes about one-half grown.
July 23.....	4-2-50 Bordeaux mixture.....	Grapes nearly full grown.

PLOT 3.

May 21.....	4-2-50 Bordeaux mixture.....	Shoots about 8 inches long.
June 2.....	.....do.....	Shoots 18 to 24 inches long.
June 15.....	.....do.....	Just after blossoming.
June 25.....	.....do.....	Grapes the size of peas.
July 8.....	.....do.....	Grapes about one-half grown.
July 23.....	.....do.....	Grapes nearly full grown.

PLOT 4.

May 21.....	3-2-50 Bordeaux mixture.....	Shoots about 8 inches long.
June 2.....	.....do.....	Shoots 18 to 24 inches long.
June 15.....	.....do.....	Just after blossoming.
June 25.....	.....do.....	Grapes the size of peas.
July 8.....	.....do.....	Grapes about one-half grown.
July 23.....	4-2-50 Bordeaux mixture.....	Grapes nearly full grown.

PLOT 6.

May 21.....	4-2-50 Bordeaux mixture, with 2 pounds of soap.	Shoots about 8 inches long.
June 2.....	.....do.....	Shoots 18 to 24 inches long.
June 15.....	.....do.....	Just after blossoming.
June 25.....	.....do.....	Grapes the size of peas.
July 8.....	.....do.....	Grapes about one-half grown.
July 23.....	4-2-50 Bordeaux mixture.....	Grapes nearly full grown.

PLOT 7.

May 21.....	3-2-50 Bordeaux mixture, with 2 pounds of soap.	Shoots about 8 inches long.
June 2.....	.....do.....	Shoots 18 to 24 inches long.
June 15.....	.....do.....	Just after blossoming.
June 25.....	.....do.....	Grapes the size of peas.
July 8.....	.....do.....	Grapes about one-half grown.
July 23.....	4-2-50 Bordeaux mixture.....	Grapes nearly full grown.



TABLE XVI.—*Treatment given ten plots in Mr. Giddings's vineyard, near Lawton, Mich., in 1908—Continued.*

PLOT 8.		
Date of spraying.	Fungicide used.	Stage of growth.
May 21.....	Copper borate mixture No. 2.....	Shoots about 8 inches long.
June 2.....	do.....	Shoots 18 to 24 inches long.
June 15.....	do.....	Just after blossoming.
June 25.....	do.....	Grapes the size of peas.
July 8.....	do.....	Grapes about one-half grown.
July 23.....	4-2-50 Bordeaux mixture.....	Grapes nearly full grown.
PLOT 9.		
May 21.....	Neutral copper acetate.....	Shoots about 8 inches long.
June 2.....	do.....	Shoots 18 to 24 inches long.
June 15.....	do.....	Just after blossoming.
June 25.....	do.....	Grapes the size of peas.
July 8.....	do.....	Grapes about one-half grown.
July 23.....	4-2-50 Bordeaux mixture.....	Grapes nearly full grown.
PLOT 10.		
May 21.....	Self-boiled lime-sulphur No. 2.....	Shoots about 8 inches long.
June 2.....	do.....	Shoots 18 to 24 inches long.
June 16.....	do.....	Just after blossoming.
June 26.....	do.....	Grapes the size of peas.
July 8.....	do.....	Grapes about one-half grown.
July 23.....	4-2-50 Bordeaux mixture.....	Grapes nearly full grown.
PLOT 11.		
May 21.....	"B" brand lime-sulphur, 1 to 50.....	Shoots about 8 inches long.
June 2.....	do.....	Shoots 18 to 24 inches long.
June 16.....	do.....	Just after blossoming.
June 26.....	do.....	Grapes the size of peas.
July 9.....	do.....	Grapes about one-half grown.
July 23.....	4-2-50 Bordeaux mixture.....	Grapes nearly full grown.

As the grape berry-moth was causing considerable loss in Mr. Giddings's vineyard, an arsenical preparation made in accordance with the directions of Prof. A. L. Quaintance, of the Bureau of Entomology, was added to the Bordeaux mixture for the second, third, and fourth applications on all the plots.

The following table shows the results of the treatment of each plot:

TABLE XVII.—*Results of spraying experiments on ten plots of Concord grapes in Mr. Giddings's vineyard, near Lawton, Mich., in 1908.*

No. of plot.	Number of applications.	Fungicide used.	Rot.	Yield.
			<i>Per cent.*</i>	<i>Baskets (8 lb.).</i>
1	6	4-4-50 Bordeaux mixture †.....	0.051	187
2	6	4-3-50 Bordeaux mixture.....	0.043	166
3	6	4-2-50 Bordeaux mixture.....	0.15	148
4	6	3-2-50 Bordeaux mixture.....	0.17	120
5	.....	Check, unsprayed.....	28.317	78
6	6	4-2-50 Bordeaux mixture, with 2 pounds of soap.....	0.411	137
7	6	3-2-50 Bordeaux mixture, with 2 pounds of soap.....	0.531	140
8	6	Copper borate mixture No. 2, with 1 pound of soap.....	2.464	125
9	6	Neutral copper acetate, 1 to 50.....	1.088	134
10	6	Self-boiled lime-sulphur No. 2.....	2.413	102
11	6	"B" brand lime-sulphur, 1 to 50.....	3.383	(‡)

\* Determined by count of rotten berries.

† Bordeaux mixture 4-2-50 was used for the sixth application on all the plots.

‡ Record wanting.

The percentages of rot were determined by actual count of the diseased berries on 1,000 average bunches, as in the previous cases. The yield in 8-pound baskets is also given for each plot except the last, the record of which is missing. The smallest percentage of rot, as indicated in Table XVII, was found on plot 2, treated with 4-3-50 Bordeaux mixture. The difference between this plot and plot 1, treated with 4-4-50 Bordeaux mixture, is, however, very slight. A portion of a vine from plot 2, showing the condition of the fruit, is illustrated in Plate IV, figure 1, and a portion of a vine from the unsprayed check, showing the general appearance of the fruit, is illustrated in Plate IV, figure 2. The lime-sulphur mixtures produced decidedly less satisfactory results than the Bordeaux mixtures. The self-boiled lime-sulphur, which was prepared with hot water, injured the foliage somewhat, and the "B" brand concentrated solution at the rate of 1 gallon to 50 gallons of water burned the foliage still more seriously, and therefore is unsafe to use in this strength. The results of the treatment with lime-sulphur were so much less satisfactory in this case than in the New York experiments in 1908, in which the first application was made with Bordeaux mixture, that considerable doubt is thrown upon the part played by lime-sulphur in controlling the rot in that case. Further experiments are needed to determine whether lime-sulphur solutions in any form or strength in which they can be used will prove a desirable substitute for Bordeaux mixture. The neutral copper acetate solution, 1 pound to 50 gallons of water, gave better results than any of the other applications except Bordeaux mixture.

The following account shows the expense of spraying and the gain from plot 2, one-third of an acre, sprayed six times with 4-3-50 Bordeaux mixture, 258 gallons being applied, and the estimated gain per acre at the same rate:

*Receipts and expenditures, plot 2, Mr. Giddings's vineyard, near Lawton, Mich., 1908.*

Yield from plot 2, sprayed, 166 8-pound baskets, at 12½ cents.....	\$20. 75
Yield from check plot, 119 8-pound baskets, at 12½ cents.....	14. 87½
Gain due to spraying.....	5. 87½
Man and team, 2 hours, at 35 cents.....	\$0. 70
Two men to carry trailers for last three sprayings, 1 hour, at 15 cents each.....	. 30
Copper sulphate, 20½ pounds, at 6 cents.....	1. 24
Stone lime, 15½ pounds, at two-thirds of a cent.....	. 10
Total cost of spraying plot, one-third of an acre.....	2. 34
Net gain due to spraying on one-third of an acre.....	3. 53½
Net gain per acre at same rate.....	10. 60½



FIG. 1.—GRAPES ON PLOT SPRAYED WITH 4-3-50 BORDEAUX MIXTURE IN THE VINEYARD OF MR. C. C. GIDDINGS, NEAR LAWTON, MICH. PHOTOGRAPHED SEPTEMBER 12, 1908. THE LOSS FROM BLACK-ROT WAS LESS THAN FIVE ONE-HUNDREDTHS OF ONE PER CENT.



FIG. 2.—GRAPES ON UNSPRAYED CHECK PLOT IN THE SAME VINEYARD AND PHOTOGRAPHED ON THE SAME DAY AS THE VINE SHOWN IN FIGURE 1. MORE THAN TWENTY-EIGHT PER CENT OF THE FRUIT WAS DESTROYED BY BLACK-ROT.



There was an additional loss on the check plot of 15.6 per cent, due to the berry-moth, making a total loss of 43.9 per cent. As this loss was almost entirely prevented on the sprayed plots without additional cost except for the poison used, the above statement does not show all the profit due to spraying.

## WORK IN NEW JERSEY.

### EXPERIMENTS IN 1908.

In former years the Concord grape was rather extensively grown in New Jersey, especially for the manufacture of grape juice. The black-rot soon became troublesome, owing to some extent, no doubt, to the climatic conditions which favor its development. Some of the earliest experiments in spraying to control the disease in this country were undertaken at Vineland, N. J., by the Department of Agriculture, in 1887. The results obtained were very satisfactory, considering the fact that spraying had only recently been introduced and that mixtures and machines were in a very crude and unsatisfactory state.

In recent years the Concord grape has been largely abandoned in New Jersey and other more disease-resistant varieties introduced. Many of these varieties, however, are not so productive or as well adapted to the manufacture of juice.

At the request of those interested in the industry and in cooperation with the New Jersey Agricultural Experiment Station the Department of Agriculture has undertaken to demonstrate that by proper methods of spraying practiced in connection with better methods of pruning, training, and cultivation, the Concord grape can still be successfully and profitably grown in that region. The part of the work pertaining to pruning, training, and cultivation was undertaken by the Office of Field Investigations in Pomology of the Bureau of Plant Industry and carried out under the immediate direction of Mr. George C. Husmann, Pomologist in Charge of Viticultural Investigations.

A small Concord vineyard, one of the very few still remaining in this region, located on the grounds of the New Jersey Training School for the Feeble Minded, at Vineland, was very kindly placed at the disposal of the writers by Professor Johnstone, superintendent of the school. The total area was about 0.75 acre. Three rows, which were pruned according to different methods, were sprayed for comparison with a single unsprayed check row, which was pruned according to the ordinary system that had been followed in the vineyard. This was a modified Kniffin system. The spraying was done with a hand pump attached to a barrel which was drawn in a cart.

The following table shows the treatment of the vineyard. As rose-bugs are usually very troublesome here, 3 pounds of arsenate of lead



were added to the Bordeaux mixture for the second and third applications.

TABLE XVIII.—*Treatment given a vineyard of Concord grapes at Vineland, N. J., in 1908.*

Date of spraying.	Fungicide used.	Stage of growth.
May 4.....	4-3-50 Bordeaux mixture.....	Shoots 6 to 8 inches long.
May 20.....	4-3-50 Bordeaux mixture, with 3 pounds of arsenate of lead.	Flowers almost ready to open.
June 8.....	do.....	Just passed blooming.
June 26.....	4-3-50 Bordeaux mixture.....	Fruit about one-third grown.
July 27.....	3-1-50 Bordeaux mixture.....	Fruit nearly grown.

The last application, of 3-1-50 Bordeaux mixture, left very little stain on the fruit and showed no signs of injury to the foliage. It gives some promise, therefore, of success as a final application when too much staining of the fruit is objectionable.

The results of the spraying were as follows: Row 1, pruned and trained according to a modified Munson system, produced 347 pounds of sound fruit; row 2, treated the same as row 1, produced 267 pounds of sound fruit. Half of row 2, pruned and trained according to a modified Munson system, produced 157 pounds of sound fruit; the other half, pruned and trained according to the Kniffin system, produced 110 pounds. This appears to show a difference of 47 pounds of fruit apparently attributable to the method of pruning and training. Row 3, which was the check row, received no spraying and was pruned according to the ordinary practice of the neighborhood. This produced only 114 pounds of fruit. It was estimated, however, that half of the loss on this row was due to rose-bugs which destroyed the young fruit immediately after the blossoms fell. The rose-bugs, however, were picked by hand from both the sprayed and the unsprayed rows.

There was practically no loss from black-rot on the sprayed rows, as only occasionally could a diseased berry be found. Comparing each of the sprayed rows with the check row, the following results are obtained:

TABLE XIX.—*Results of spraying and pruning experiments on a vineyard of Concord grapes at Vineland, N. J., in 1908.*

No. of row.	Production.	Total loss.	Loss by rose-bugs.	Loss by black-rot.	
	Pounds.	Pounds.	Pounds.	Pounds.	Per cent.
1 (sprayed).....	347	(No loss.)	(No loss.)	(No loss.)	00.0
3 (check).....	114	233	116½	116½	31.3
2 (sprayed).....	267	(No loss.)	(No loss.)	(No loss.)	00.0
3 (check).....	114	153	76½	76½	31.9

The average of the crops from the two sprayed rows is 307 pounds. The crop on the check row being only 114 pounds shows a loss of 193 pounds; allowing one-half of this for loss by rose-bugs, the loss of

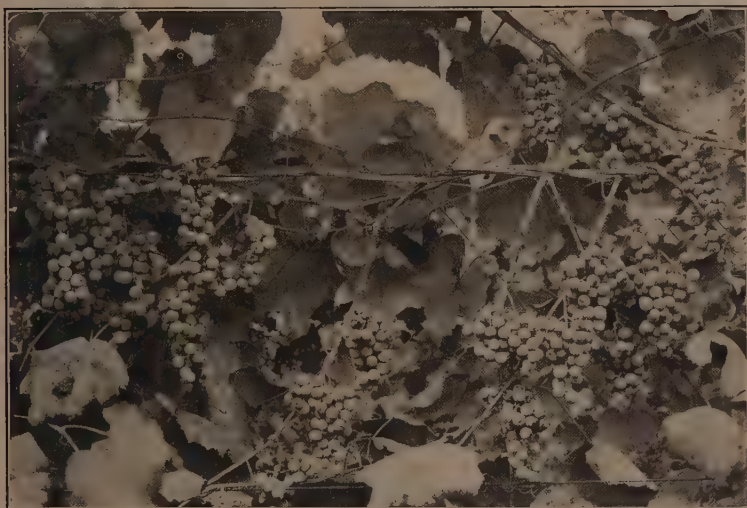


FIG. 1.—PORTION OF A VINE SPRAYED WITH BORDEAUX MIXTURE, VINELAND, N. J., 1908, SHOWING PRACTICALLY NO LOSS FROM BLACK-ROT.



FIG. 2.—PORTION OF AN UNSPRAYED CHECK ROW IN THE SAME VINEYARD AS THE VINE SHOWN IN FIGURE 1, 1908, SHOWING 31 PER CENT OF LOSS FROM BLACK-ROT AND ABOUT THE SAME AMOUNT OF LOSS FROM ROSE-BUGS.



96.5 pounds, or 31.4 per cent, was caused by black-rot. In other words, the sprayed rows show practically no loss from rot and the unsprayed check row shows over 31 per cent, or a total loss of over 62 per cent, when the injury from rose-bugs, which was also largely prevented by the spraying, is added.

A portion of a sprayed vine showing the condition of the fruit is illustrated in Plate V, figure 1, and a part of an unsprayed vine from the check row is shown in figure 2 of the same plate.

### COMPARISON OF RESULTS OBTAINED WITH DIFFERENT FORMULAS OF BORDEAUX MIXTURE.

The following table gives in condensed form the results of the tests of different formulas of Bordeaux mixture:

TABLE XX.—*Comparison of results secured from use of different formulas of Bordeaux mixture.*

#### PENNSYLVANIA.

Formula used.	Year.	Number of applications.	Results.
			<i>Yield, baskets.</i>
4-4-50 Bordeaux mixture.....	1908	3	554
4-3-50 Bordeaux mixture.....	1908	3	479

#### NEW YORK.

			<i>Rot, per cent.</i>
4-4-50 Bordeaux mixture, with soap.....	1907	7	6.6
5-5-50 Bordeaux mixture.....	1907	5	6.3
4-4-50 Bordeaux mixture, with soap.....	1907	5	7.2
4-2-50 Bordeaux mixture, with soap.....	1908	6	0.49
4-2-50 Bordeaux mixture.....	1908	6	0.79
3-2-50 Bordeaux mixture.....	1908	6	0.79
4-3-50 Bordeaux mixture.....	1908	6	1.06
4-4-50 Bordeaux mixture.....	1908	6	1.9

#### MICHIGAN (MRS. SMITH'S).

5-5-50 Bordeaux mixture.....	1907	7	28.3
4-4-50 Bordeaux mixture, with soap.....	1907	7	28.7
4-3-50 Bordeaux mixture.....	1908	7	0.034
4-2-50 Bordeaux mixture.....	1908	7	0.178
4-4-50 Bordeaux mixture.....	1908	7	0.197

#### MICHIGAN (MR. TOWERS'S).

4-4-50 Bordeaux mixture.....	1908	6	0.03
4-2-50 Bordeaux mixture.....	1908	6	0.042
5-5-50 Bordeaux mixture.....	1908	6	0.051
5-3-50 Bordeaux mixture.....	1908	6	0.064
Do.....	1908	6	0.0007

#### MICHIGAN (MR. GIDDINGS'S).

4-3-50 Bordeaux mixture.....	1908	6	0.043
4-4-50 Bordeaux mixture.....	1908	6	0.051
4-2-50 Bordeaux mixture.....	1908	6	0.15
3-2-50 Bordeaux mixture.....	1908	6	0.17
4-2-50 Bordeaux mixture, with soap.....	1908	6	0.41

From a comparison of these tables it may perhaps be justifiable to draw some tentative conclusions in regard to the best formula for Bordeaux mixture as a preventive of black-rot.

In the cases in which the 4-4-50 formula was used in comparison with the 5-5-50 formula, the former proved best in New York in 1907 and in Michigan in 1908, and gave almost equally satisfactory results in Michigan in 1907, there being only four-tenths of 1 per cent difference shown.

In the cases in which the 4-3-50 formula was compared with the 4-4-50 formula, the former gave slightly better results in New York in 1908 and decidedly better results in Michigan in Mrs. Smith's vineyard in 1908, and slightly better results in Michigan in Mr. Giddings's vineyard in 1908. There was very little difference in the results in the other cases in which these formulas were used—Pennsylvania in 1908 and Michigan, Mr. Towers's vineyard, in 1908. The 4-3-50 mixture gave entirely satisfactory results in the New Jersey experiment also.

The 4-2-50 formula gave better results than either the 4-4-50 or the 4-3-50 formula in one case, New York, 1908, and was second best in two other experiments, Michigan, Mrs. Smith's vineyard, 1908, and Mr. Towers's vineyard, 1908.

The 3-2-50 formula did not stand above third place in any of the cases in which it was used.

The 4-4-50 formula is found at the head of the table in three cases, and the 4-3-50 in two cases. The writers believe, however, that the 4-3-50 formula, which was not used in all the experiments in comparison with the 4-4-50, will prove the best for general use, in view of all the circumstances and the results thus far obtained.

#### GENERAL CONCLUSIONS.

When fresh stone lime is used in the preparation of Bordeaux mixture, as should always be done if possible, 3 pounds of lime will be ample to more than neutralize 4 pounds of copper sulphate, and since according to recent investigations already mentioned a great excess of lime is likely to prove detrimental rather than beneficial this quantity is preferable.

Of the mixtures other than Bordeaux which have been used, none has shown sufficiently good results to give promise of being a profitable substitute for it. Of such mixtures, neutral copper acetate gave the best results in Michigan, Mr. Giddings's vineyard, 1908, and also in New York in 1908. Neutral copper acetate solution also promises to be one of the most valuable fungicides for use as a final application when there is need of a nonstaining preparation. It will, however,



be desirable to compare this carefully with the ammoniacal solution of copper carbonate to determine more accurately their relative value.

In nearly all of their experiments the writers have tried to determine the value of adding an adhesive preparation, or "sticker" as it is sometimes called. Resin-fishoil soap has been used for this purpose. The percentage of rot on the plots on which this was used has never been sufficiently reduced to justify the additional expense and trouble involved.

A study of the tables giving the results of the spraying experiments will show that where different numbers of applications were made in the same series, five applications made at the proper times gave nearly or quite as satisfactory results as six, seven, or even eight. Unless a vineyard has been neglected or rot has destroyed the greater part of the crop the preceding season, an application before the buds open, judging from the experiments of the writers, is not profitable; neither does spraying when the shoots are less than 6 inches long seem to materially improve the results.

Different forms of spraying outfits have been used in these experiments, as has already been pointed out. It is impossible to state that any one kind is best, as the conditions under which the work is to be done and other circumstances must always be taken into consideration. The writers have done very satisfactory work with geared traction outfits, with carbonic-acid-gas sprayers, and with gasoline power sprayers. It has been found necessary in some cases to modify the outfits somewhat, especially the arrangement and the number of the stationary nozzles.

In cases where the rot is severe and the season favorable for its development, in order to secure the most satisfactory results it is necessary to use trailers or long leads of hose which can be handled by persons walking behind the machine and directing the nozzles so as to thoroughly cover the fruit and foliage. This can not be done satisfactorily by stationary nozzles when the foliage is very heavy.

#### SUMMARY.

Bordeaux mixture prepared according to the 4-3-50 formula has been found to be as effective in preventing black-rot as the formulas in which larger quantities of copper sulphate and lime are used.

Five or six applications, beginning when the shoots were 8 inches to 1 foot long, gave generally as good results as when one or two additional earlier applications were made, showing apparently that no particular benefit is derived from dormant applications or from applications made when the shoots are less than 8 inches long.

Where unsprayed grapes were a total loss from black-rot in 1907 the rot on the sprayed plots was reduced to 28.3 per cent. The next

season, 1908, when the rot was almost equally bad on unsprayed vineyards, the rot on the same sprayed plots was reduced to much less than 1 per cent, showing apparently the great cumulative effect of treatment for two seasons.

The gain due to spraying varied in the different vineyards, according to the severity of the rot, the number of sprayings, the productiveness of the vines, and the cost of materials and labor, from \$10.60 to \$62.30 per acre.

The experiments have shown the necessity of covering the vines thoroughly with a fine spray of properly prepared Bordeaux mixture. When the black-rot is serious or the foliage is very heavy it is necessary to use trailers and have the nozzles directed by hand, as fixed nozzles will not properly cover the foliage and fruit.

The tests of various lime-sulphur preparations have not yet been sufficient to determine their value as a preventive of black-rot.

Neutral copper acetate, 1 pound to 50 gallons of water, has been found to be the best nonstaining preparation tested in these experiments for final applications.

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